SEISMIC VULNERABILITY OF MASONRY HERITAGE BUILDINGS IN MALTA

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Introduction

The structural behaviour of masonry heritage buildings in Malta subjected to seismic action is a major risk in conserving such buildings. This is because Malta lies on a seismic zone which was subjected to high intensity earthquakes in the past (Galea, 2007). Many of the existing masonry heritage buildings were subjected to major earthquakes of 1693, 1743 and 1856, with repairs ranging from minor repairs to partial rebuilding (Abela, 1969; Galea, 2007). The survival of such buildings does not determine the degree of seismic resistance to any future strong tremor. The study will explore the possibility to determine the seismic vulnerability of masonry heritage buildings using Applied Element Method (AEM), a numerical structural modelling. Since AEM was never used to determine seismic vulnerability of masonry heritage buildings in Malta, simple masonry heritage building typology is being analysed in this study.

Numerical structural Modelling for Masonry Heritage buildings

Numerical structural modelling is widely used to analyse buildings and predict their behaviour under seismic action (Roca, Cervera, Gariup, & Pela', 2010). In general, two different methods are used. These are the Finite Element Method (FEM) and Discrete Element Method (DEM) (Roca, Cervera, Gariup, & Pela', 2010; Smoljanović, Živaljić, & Nikolić, 2013). FEM is used very successfully to simulate pre failure situations and the global behaviour of large buildings (Mistler, Butenweg, &Meskouris, 2006) but it cannot accurately simulate post cracking scenarios. DEM's main feature is that it can simulate the separation between each masonry block without knowing the failure mechanism of the building (Giordano, Mele, & De Luca, 2002).

Another important aspect in Numerical modelling is the element size. The size of the element depends on the level of detail of the building being simulated. In studies performed on masonry buildings (Lemos, 2007; Dimitri, De Lorenzis, &Zavarise, 2011; Casolo, Milani, Uva, &Alessandri, 2013); DeJong&Vibert, 2012; Ulrich, Gehl, Negulescu, &Foerster, 2012), it can be concluded that if the element size was the same as the masonry unit, and placed on each other as actual, and using DEM, the failure mechanism of the building can be modelled satisfactorily.

AEM (Meguro &Tagel-Din, Applied Element Method for Structural Analysis: Theory and Application for Linear Materials, 2000), a numerical mathematical model which forms part of the DEM family (Lemos, 2007) was chosen because of its ability to simulate the behaviour of the masonry heritage building from initial loading to total collapse (Meguro &Tagel-Din, Applied Element Method Used for Large Displacement Structural Analysis, 2002). This is achieved in AEM by modelling the masonry building by rigid elements, connected together with matrix springs (Normal and Shear springs) (vide Figure 1), which can simulate both the material stresses and deformations in the elements (Meguro &Tagel-Din, Applied Element Method for Structural Analysis: Theory and Application for Linear Materials, 2000). An additional feature when compared to DEM is that contact between two detached elements is simulated by contact springs (Normal and Shear springs) (Tagel-Din, 2009, pp. 7-23).

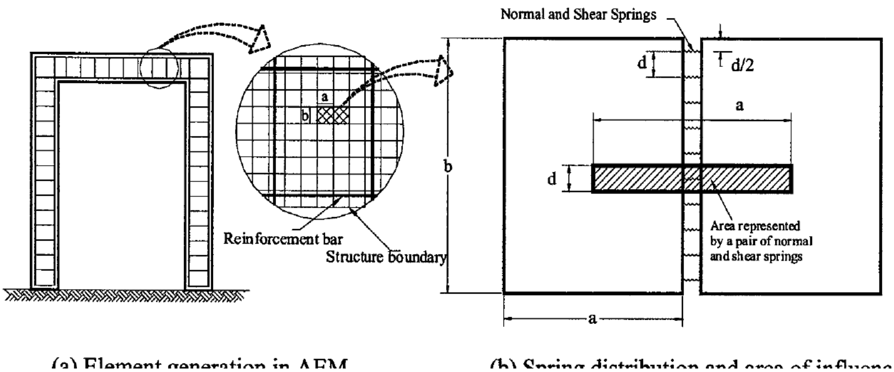

Figure 1. Modelling of the structure in the AEM (Souce: (Meguro &Tagel-Din, Applied Element Method Used for Large Displacement Structural Analysis, 2002))

Seismic analysis of a simple Masonry Heritage building typology

Three aspects that form the key part of the study are selecting the simple masonry heritage building typology, the simulation of the building in AEM and the ground motion adopted. Since AEM was never used to simulate masonry heritage buildings in Malta, the building selection involves identifying a building typology with simple masonry technology in order to limit as many variables as possible.

The simulation of the simple masonry heritage building involves the rationalisation of the actual building without eliminating main building irregularities. This can be grouped by regularising the masonry unit sizes, selecting common masonry and mortar properties and selection of ground-building conditions.

No past seismic record of earthquakes that have damaged masonry heritage buildings exists (Galea, 2007). Thus the ground motion that is adopted for the study is to reflect the maximum earthquake intensity that the masonry heritage building can sustain, since the earthquake intensity is one of the main parameters that influence the seismic vulnerability of the building (Tomaževič, 1999)

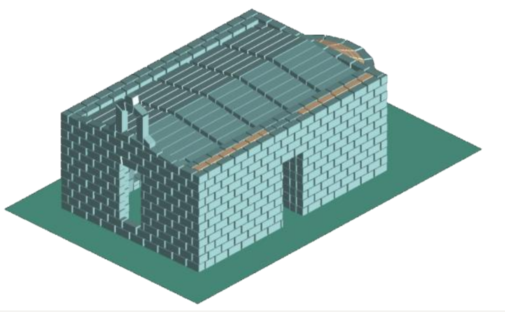

Figure 2. A simple masonry heritage building modeled on AEM.

Conclusion

The study offers more understanding on the seismic vulnerability on heritage buildings, starting from observing the seismic behaviour of simple masonry heritage building typology. Since no seismic record of damaging tremors in Malta exists, any historical record of buildings damaged due to past tremors was collected to understand the past seismic vulnerability of heritage buildings. Then different numerical structural modelling used for heritage buildings were studied from which AEM was chosen. From the seismic analysis by AEM the seismic vulnerability of Heritage buildings was better understood. One factor that greatly influences the seismic vulnerability which cannot always be mimicked with AEM is the quality of workmanship including lack of maintenance of the building which increases the seismic vulnerability of masonry heritage buildings in general, a reason which was also noted in previous earthquakes.

Acknowledgements

I would like to express my gratitude and appreciation to SIMIT team of the Faculty of the Built Environment and the Seismic Monitoring & Research Unit of the University of Malta that made possible the study to be performed and for all the help and assistance provided. I would also like to thank Din l-Art Ħelwa for their kind permission to use heritage buildings that they manage for the study. Finally I give thanks to Applied Science International, LLC for providing the AEM software used in the study.

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